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FUEL ASSEMBLY FOR A PRESSURIZED WATER NUCLEAR REACTOR
[Bränslepatron för en nukleär tryckvattenreaktor]

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BACKGROUND OF THE INVENTION AND PRIOR ART /1[1]

The present invention relates to a fuel assembly for a pressurized water nuclear reactor, said fuel assembly comprising a first support plate, a second support plate, a plurality of fuel rods, a plurality of guide tubes for control rods that extend from the first to the second support plate, and a plurality of spreaders, arranged so as to hold the fuel rods and guide tube at predetermined distances from one another, the guide tubes being of the type that, viewed in at least one cross section that is perpendicular to direction of the fuel assembly's main extension, has essentially the same perimeter as the fuel rods and said first support plate having a plurality of through holes, dimensioned for receiving control rods of a dimension such that the control rods are suitable for insertion into said type of guide tube.

Figure 1 shows in schematic representation one example of a previously known fuel assembly 10 for a pressurized water nuclear reactor. The fuel assembly 10 comprises a plurality of fuel rods 12 and a plurality of guide tubes 13 for control rods. The guide tubes 13 are fixed in a first support plate 18 and in a second support plate 20. Thus, the guide tubes 13 extend from the first support plate 18 to the second support plate 20. The fuel assembly 10 is normally arranged vertically. In this case, the first support plate 18 is usually called the top plate and the second support plate 20 is

[1] Number in the margin indicates pagination in the foreign text.

called the bottom plate. Moreover, the fuel assembly 10 comprises a plurality of spreaders 16, which are arranged so as to hole the fuel rods 12 and the guide tubes 13 at a predetermined distance from one another. The fuel assembly 10 can also include a second elongated element, e.g., a so-called instrumentation tube 14. Thus, the fuel assembly 10 is held together between the first support plate 18 and the second support plate 20 in that the guide tubes 13 are fixedly arranged in said plates 18, 20. Moreover, the fuel assembly 10 is held together with the help of the spreaders 16. The first support plate 18 is made with through holes 19 (in Figure 1, such a through hole 19 is indicated by a dashed line) at positions where the guide tube 13 is arranged. This means that control rods can be inserted into the guide tubes 13 through the first support plate 18. Such control rods contain an absorber, typically boron, which absorbs neutrons. By absorbing neutrons, it is possible to reduce the nuclear reaction in the reactor. Thus, the nuclear reaction in a nuclear reactor can be reduced or ended entirely by inserting the control rods into the guide tubes 13 through the above-mentioned holes 19 in the first support plate 18. As mentioned above, the first support plate 18 is usually a top plate and, in this case, the control rods are inserted into the fuel assembly from above. There are nuclear reactors with various types of control rods. The present invention relates to a fuel assembly 10 that is designed for relatively narrow control rods, of such dimensions that they can be lowered into guide

tubes 13 having an outer dimension that essentially corresponds to the outer dimensions of the fuel rods 12.

Figure 2 shows a cross section indicated as A-A in Figure 1. A fuel assembly 10 can have various numbers of fuel rods 12 and guide tube 13. In the embodiment shown, the spreader 16, and thus the fuel assembly 10, has 289 cells 17, through which fuel rods 12, guide tubes 13, or other elements can extend. Figure 2 shows that the fuel assembly 10 has a centrally placed instrumentation tube 14. The cells 17 for the various elongated elements are essentially of the same size. This means that the guide tubes 13 have an outer diameter that essentially corresponds to the outer diameter of the fuel rods 12. The fuel assembly 10 shown in Figure 2 has 24 guide tubes 13 for control rods. These guide tubes 13 are fixed in the bottom plate 20 and in the top plate 19 in a conventional manner.

It should be pointed out that, for the sake of simplicity, the /3 fuel rods are not shown in Figure 2. However, the fuel rods 12 are preferably arranged in all, or at least most, of the empty cells 17 shown in Figure 2.

When the nuclear reactor is in operation, the fuel rods 12 are cooled by a coolant, usually water, which flows through the fuel assembly 10, typically from bottom to top. The coolant can also flow upward through the guide tubes 13. In this way, the upward flowing coolant creates a resistance against the control rods, when the latter are lowered into the guide tubes 13. This resistance caused by

the coolant helps assure that the control rods will not drop too quickly into the guide tubes 13. The fuel assembly 10 is usually held in place in the nuclear reactor in that the bottom plate 20 rests on a lower support surface and the fuel assembly 10 is provided with a resilient means 24, which rests against an upper support surface situated above the fuel assembly 10, thereby exerting a downward force on the fuel assembly 10. The fuel rods 12, the guide tubes 13, the spreaders 16, and other parts included in the fuel assembly 10 may be manufactured of various materials that are suitable for the surroundings in which the fuel assembly 10 is used. For example, said material may be a zirconium alloy.

The guide tubes 13 contribute to the rigidity of the fuel assembly 10. The fuel rods 12 also contribute to a certain extent to the rigidity of the fuel assembly 10. The contribution of the fuel rods 12 to the rigidity varies with the time during which the fuel assembly 10 has been arranged in a nuclear reactor that is in operation. This is due, in part, to the fact that the fuel assembly 10 is subjected to powerful neutron irradiation when the nuclear reactor is in operation. This affects the various components that are part of the fuel assembly 10. The fuel rods 12 are usually held in place in the spreaders 16 with the help of resilient elements (not shown), which hold a fuel rod 11 fixed in a cell 17 in the spreader 16. These resilient elements tend to lose a certain amount of their resilience, i.e., they soften, the longer the fuel assembly 10 is

used in an operating reactor. As a result, the contribution of the 14
fuel rods 12 to the rigidity of the fuel assembly 10 can be reduced somewhat over time.

When the material used in the various components of the fuel assembly 10 is subjected to irradiation by neutrons, which occurs during operation of the nuclear reactor, this material, and thus these components, tends to increase in size. Thus, the guide tubes 13 also tend to grow, which means, in turn, that the entire fuel assembly 10 tends to become longer over time. However, the fuel assembly 10 is usually held in place between an upper and a lower support surface. It should also be noted that the resilient means 24, which is normally situated above the top plate 18, is subjected to less neutron radiation than other parts of the fuel assembly 10. Because of this, the resilient means 24 is not affected as much by the neutron radiation and, thus, does not tend to soften to a particularly great degree. Since the resilient means 1-4 exert a downward pressure on the fuel assembly 10 and since the fuel assembly 10 has a tendency to increase in size, there is a risk that the fuel assembly 10 will become tilted or bent over time. A bent fuel assembly 10 can also affect other nearby fuel assemblies 10 in a nuclear reactor, so that a certain portion of the fuel assemblies 10 in the nuclear reactor risk becoming bent or tilted over time. Such bent fuel assemblies 10 can reduce the performance of the nuclear reactor and even lead to crack formation in the fuel rods 12.

SUMMARY OF THE INVENTION

The object of the present invention is to improve the rigidity of a fuel assembly of the type mentioned at the outset, in order to prevent the fuel assembly from becoming bent or tilted.

This object is achieved with the fuel assembly described at the outset, which is characterized by the fact that the fuel assembly includes at least one stiffening element, which extends from the first support plate to the second support plate and which has a perimeter, as viewed in the above-mentioned cross section, that is appreciably larger than the above-mentioned perimeter of the above-mentioned guide tubes or fuel rods. /6

Providing the fuel assembly with one or more such stiffening elements produces a significantly more rigid design. In this way, the tendency for the fuel assembly to bend or become tilted is reduced. Such a more rigid fuel assembly can also be used to counter bending of surrounding fuel assemblies in a fuel core. Thus, in a fuel core that already contains bent fuel assemblies, one or more fuel assemblies can be replaced with fuel assemblies in accordance with this invention. In this way, additional bending of the fuel assemblies present in the fuel core is countered. The fuel assembly in accordance with this invention can also affect surrounding fuel assemblies, so that the latter are straightened to a certain extent.

In accordance with one embodiment of the invention, the fuel assembly contains a plurality of the above-mentioned stiffening

elements. The presence of several stiffening elements in the fuel assembly further increases the rigidity of the fuel assembly.

In another embodiment of the invention, the above-mentioned stiffening element is hollow. Making the stiffening element hollow produces good rigidity, without requiring so much material for the stiffening element.

According to another embodiment of the invention, the above-mentioned stiffening element, as viewed in said cross section, has a polygonal outer perimeter line. For example, the stiffening element can be triangular or square. This makes the stiffening element relatively easy to arrange in a fuel assembly.

In another embodiment of the invention, the above-mentioned stiffening element, as viewed in the above-mentioned cross section, has a circular outer perimeter line. Such a circular stiffening element has good rigidity and the same rigidity in various bending directions. /6

In yet another embodiment of the invention, the above-mentioned stiffening element has a perimeter that, viewed in the above-mentioned cross section, has at least twice the perimeter of one of the above-mentioned fuel rods. Such a dimension on the part of the stiffening element contributes to the rigidity.

According to another embodiment of the invention, the stiffening element has a perimeter that, as viewed in said cross section, is at least three times the perimeter of the above-mentioned fuel rods. By

increasing the dimensions of the stiffening element, additionally improved rigidity in the fuel assembly may be achieved.

According to another embodiment of the fuel assembly, the above-mentioned stiffening element is hollow and is arranged in such a position in the fuel assembly that it encompasses at least one position in the fuel assembly that is designed to receive at least one control rod that is inserted into the fuel assembly through one of the above-mentioned through holes in the first support plate. Thus, the stiffening element can be arranged in a control rod position without hindering the control rod from serving its function.

According to another embodiment of the invention, at least one of the above-mentioned guide tubes is arranged in the stiffening element. Thus, the stiffening element encompasses the guide tube. Thus, the guide tube can be retained and it can be dimensioned for receiving a control rod. In this way, movement of the control rod into the guide tube is not affected by the stiffening element.

According to an advantageous embodiment of the invention, the fuel assembly 2-6 has stiffening elements. Using a plurality of stiffening elements produces additionally improved rigidity in the fuel assembly.

According to another embodiment of the invention, the fuel 17
assembly has an essentially rectangular outer limit, as viewed in the above-mentioned cross section, and it defines a central longitudinal axis, the distance between the above-mentioned stiffening elements

and the closest corner in the above-mentioned rectangular outer limit being less than the distance between the stiffening element and the above-mentioned central longitudinal axis. In other words, this means that the stiffening element is placed relatively close to one corner of the fuel assembly. This provides a particularly advantageous stiffening of the fuel assembly.

According to another embodiment of the invention, the above-mentioned stiffening element is hollow and is arranged in such a position in the fuel assembly that it encompasses at least one control rod position in the fuel assembly that is designed to receive a control rod that is inserted into the fuel assembly through one of the above-mentioned through holes in the first support plate, this at least one control rod position being situated closer to one of the corners in the fuel assembly than any other control rod position defined by the above-mentioned through holes in the first support plate. This means that the stiffening element is arranged so as to encompass the control rod that is arranged closes to a corner in the fuel assembly. Thus, the stiffening element allows a control rod to be inserted therein at the same time that the stiffening element is situated near one corner, which provides increased rigidity of the fuel assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be explained exemplary embodiments and with reference to the accompanying drawings.

Figure 1 shows in schematic form a side view of a previously known fuel assembly for a pressurized water nuclear reactor.

Figure 2 shows in schematic form a cross section in the direction A-A of the fuel assembly in Figure 1. /8

Figure 3 shows in schematic form a side view of a fuel assembly according to the present invention.

Figure 4 shows in schematic form a cross section in the direction B-B of the fuel assembly in Figure 3.

Figures 5-8 show in schematic form similar cross sections as in Figure 4 of various embodiments of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THIS INVENTION

As described above, Figures 1 and 2 show one example of a previously known fuel assembly 10 for a pressurized water nuclear reactor.

An embodiment of the present invention will now be described, with reference to Figure 3 and Figure 4. The fuel assembly 10 comprises a first support plate 18, a second support plate 20, a plurality of fuel rods 12, a plurality of guide tubes 13 for control rods, and a plurality of spreaders 16. The guide tubes 13 extend from the first support plate 18 to the second support plate 20 and are fixedly arranged in said support plates 18, 20. The guide tubes 13 are of the type that, if viewed in a cross section that is perpendicular to the main direction of extent of the fuel assembly 10 (e.g., in the cross section shown in Figure 4), has essentially the

same perimeter as the fuel rods 12. The first support plate has a plurality of through holes 19, which are dimensioned to receive control rods of such dimension that they are adapted to being inserted into said type of guide tube 13.

The fuel assembly 10 includes at least one stiffening element 30. In the embodiment shown in Figures 3 and 4, the fuel assembly 10 has four stiffening elements 30. These stiffening elements 30 extend from the first support plate 18 to the second support plate 20 and are fixed in said support plates 18, 20. Moreover, these stiffening elements 30 has a perimeter, as viewed in the cross section as in Figure 4, that is considerably larger than the perimeter of the guide tubes 13 or of the fuel rods 12.

It should be pointed out that, for the sake of clarity, the spreader cells 17 are marked in the same manner in Figures 4 to 8 as in Figure 2. In practice, of course, the spreaders 16 must be adapted to provide space for the stiffening elements 30. This means that the spreaders 16 must be provided with a number of larger cells 17 to provide room for the stiffening elements 30. Moreover, the fuel rods 12 are not shown in Figures 4-8. Thus, most or, preferably, all the empty cells 17 contain fuel rods 12.

According to the embodiment shown in Figures 3 and 4, the stiffening element 30 has a circular outer perimeter line. Moreover, the stiffening elements 30 are hollow. Thus, the stiffening elements 30 are tubular. The stiffening element 30 preferably has a perimeter,

as viewed in the cross section shown in Figure 4) that is at least two times the perimeter of the fuel rods 11 or at least 1.5 times the perimeter of the fuel rods 11.

The stiffening element 30 in Figure 3 and 4 is arranged in such positions in the fuel assembly 10 that they encompass a position in the fuel assembly 10 in which a control rod is intended to be inserted. Moreover, the stiffening element 30 contains a guide tube 13, which thus extends through the stiffening element 30. The stiffening element 30 can be provided with support means (not shown) for holding the guide tube 13 at a suitable distance in the stiffening element 30. Alternatively, the guide tube 13 can be fixed by welding in the stiffening element 30. It should be pointed out that, according to one possible alternative, no guide tube 13 is arranged in the stiffening element 30, even if the stiffening element 30 is arranged in a position in the fuel assembly 10 for receiving a control rod. If a control rod is inserted or drops down into a stiffening element 30 which does not contain a guide tube 13 and which has a larger inner diameter than a guide tube 13, then the control rod meets a lower resistance by the coolant that is present in or flowing through the stiffening element 30. In this case, /10 the stiffening element 30 should preferably be provided with some flow control element in the stiffening element 30, to make sure the control rod meets with a suitable resistance by the coolant flowing up through the fuel assembly 10.

The fuel assembly 10 shown has an essentially rectangular shape, as viewed in the cross section according to Figure 4. The fuel assembly 10 defines a central longitudinal axis 32. This axis 32 coincides in the case shown here with the instrumentation tube 14. To achieve good stability in the fuel assembly 10, the stiffening element 30 is arranged closer to corner 34 of the fuel assembly 10 than the center of the fuel assembly 10. As shown in Figure 4, the stiffening elements 30 are preferably arranged such that they encompass the control rod position that is situated closes to the corner 34.

Figures 5-8 show alternative embodiments of the invention. The same references numbers are used for corresponding parts in all figures.

Figure 5 shows another embodiment with four stiffening elements 30. The stiffening elements 30 in this case have a polygonal outer perimeter line. More specifically, the stiffening element 30 is square in this case. The stiffening element 30 in this embodiment encompasses about four cells 17 of the size that the fuel rods 11 and the guide tubes 13 are designed to be arrange in. This means that a spreader 16 can be adapted relatively easily to this type of square stiffening element 30. Thus, the spreader 16 should be provided with a number of special cells for the stiffening elements 30, said cells being approximately four times the size of a normal cell 17.

Figure 6 shows one embodiment, where the stiffening element 30 has a triangular cross section. This type of stiffening element 30 takes up relatively little space in the fuel assembly 10.

Figure 7 shows one embodiment, where the stiffening element 30 /11
has a significantly larger perimeter than in the previously shown embodiments. The stiffening element 30 in accordance with this embodiment has a perimeter that is more than three times the perimeter of a fuel rod 12. The stiffening elements 30 in this embodiment are arranged so that they enclose two control rod positions. In this case, two guide tube 13 are arranged in each stiffening element 30. Since the stiffening elements 30 have a relatively large diameter, the rigidity of the fuel assembly 10 is improved.

Figure 8 shows one embodiment, in which the stiffening element 30 is arranged in positions that do not receive any control rods. In the case shown, the stiffening element 30 is arranged closest to the corner 34 in the fuel assembly 10.

It should be pointed out that in all embodiments the stiffening element 30 preferably has the same appearance in each cross section between the top plate 18 and the bottom plate 20. It is also conceivable, however, for the cross-sectional shape of the stiffening element 30 to vary. The stiffening element 30 preferably encompasses no fuel rods 12. If the stiffening element 30 is sufficiently large,

however, it is also conceivable for one or more fuel rods 12 to extend through the stiffening element 30.

With the present invention, a fuel assembly 10 can be obtained that has significantly improved rigidity, compared to previous fuel assemblies. At the same time, the fuel assembly 10 has the advantage that it can be used in a nuclear reactor with the type of narrow control rods that fit into the guide tubes 13, of the type described above. This means that the nuclear reactor does not need to be adapted for other types of control rods. The stiffening element can expediently be made of a zirconium alloy.

This invention is not limited to the embodiments shown, but can be varied and modified within the scope of the following claims. /12

Patent Claims

1. A fuel assembly (10) for a pressurized water nuclear reactor, said fuel assembly (10) comprising a first support plate (18), a second support plate (20), a plurality of fuel rods (12), a plurality of guide tubes (13) for control rods extending from the first support plate (18) to the second support plate (20) and a plurality of spreaders (16) arranged so as to hold fuel rods (12) and guide tubes (13) at a predetermined distance from one another, said guide tubes (13) being of the type that, as viewed in at least one cross section that is perpendicular to the main direction of extent of the fuel assembly (10), has essentially the same perimeter as the fuel rods (12) and said first support plate (18) contains a plurality of through holes (19), dimensioned so as to receive control rods of a dimension such that the control rods are adapted to be inserted into said type of guide tubes (13), characterized in that the fuel assembly (10) has at least one stiffening element (30), which extends from the first support plate (18) to the second support plate (20) and which has a perimeter, as viewed in said cross section, that is considerably larger that said perimeter of said guide tubes (13) or fuel rods (12).

2. A fuel assembly in accordance with Claim 1, characterized by the fact that the fuel assembly (10) contains a plurality of the above-mentioned stiffening elements (30).

3. A fuel assembly in accordance with one of the previous claims, characterized by the fact that the above-mentioned stiffening elements (30) are hollow.

4. A fuel assembly in accordance with one of the previous claims, characterized by the fact that the above-mentioned stiffening elements (30), as viewed in said cross section, have a polygonal outer perimeter line.

5. A fuel assembly in accordance with one of the claims 1-3, characterized by the fact that the above-mentioned stiffening elements (30), as viewed in said cross section, have a circular outer perimeter line.

6. A fuel assembly in accordance with one of the previous /14 claims, characterized by the fact that the above-mentioned stiffening elements (30) have a perimeter, as viewed in said cross section, that is at least twice the perimeter of one of the above-mentioned fuel rods (12).

7. A fuel assembly in accordance with Claim 6, characterized by the fact that the above-mentioned stiffening elements (30) have a perimeter, as viewed in said cross section, that is at least three times the perimeter of one of the above-mentioned fuel rods (11).

8. A fuel assembly in accordance with one of the previous claims, characterized by the fact that the above-mentioned stiffening elements (30) are hollow and arranged in a position in the fuel assembly (10) such that they encompass at least one position in the

fuel assembly (10) that is intended to receive at least one control rod, which is inserted into the fuel assembly (10) through one of the above-mentioned through holes (19) in the first support plate (18).

9. A fuel assembly in accordance with Claim 8, characterized by the fact that at least one of the above mentioned guide tubes (13) is arranged in the stiffening element (30).

10. A fuel assembly in accordance with one of the previous claims, characterized by the fact that the fuel assembly (10) has 2-6 stiffening elements (30).

11. A fuel assembly in accordance with one of the previous claims, characterized by the fact that the fuel assembly (10) has an essentially rectangular outer perimeter, as viewed in the above-mentioned cross section, and defines a central longitudinal axis (32), the distance between the above-mentioned stiffening element (30) and the nearest corner (34) of said rectangular outer perimeter being less than the distance between the stiffening element (30) and said central longitudinal axis (32).

12. A fuel assembly in accordance with one of the previous patent claims, characterized by the fact that the above-mentioned stiffening element (30) is hollow and arranged in a position in the fuel assembly (10) such that it encompasses at least one control rod position in the fuel assembly (10), which is intended to receive a control rod that is inserted into the fuel assembly (10) through one of the above-mentioned through holes (19) in the first support plate /15

(18), said at least one control rod position being situated closer to one of the corners (34) of the fuel assembly (10) than is any other control rod position defined by the said through holes (19) in the first support plate (18).

Summary /16

This invention relates to a fuel assembly (10) for a pressurized water nuclear reactor. The fuel assembly (10) comprises a first support plate (18), a second support plate (20), a plurality of fuel rods (12), a plurality of guide tubes (13) for control rods, and a plurality of spreaders (16). The guide tubes (13) are of the type that, as viewed in a cross section that is perpendicular to the main direction of extent of the fuel assembly (10), has essentially the same perimeter as the fuel rods. The invention is characterized by the fact that the fuel assembly (10) includes at least one stiffening element (30), which extends from the first support plate (18) to the second support plate (20). The stiffening element (30) has a perimeter that, as viewed in the above-mentioned cross section, is considerably larger than the perimeter of the above-mentioned guide tube (13) or fuel rod (12).

(Fig. 3)

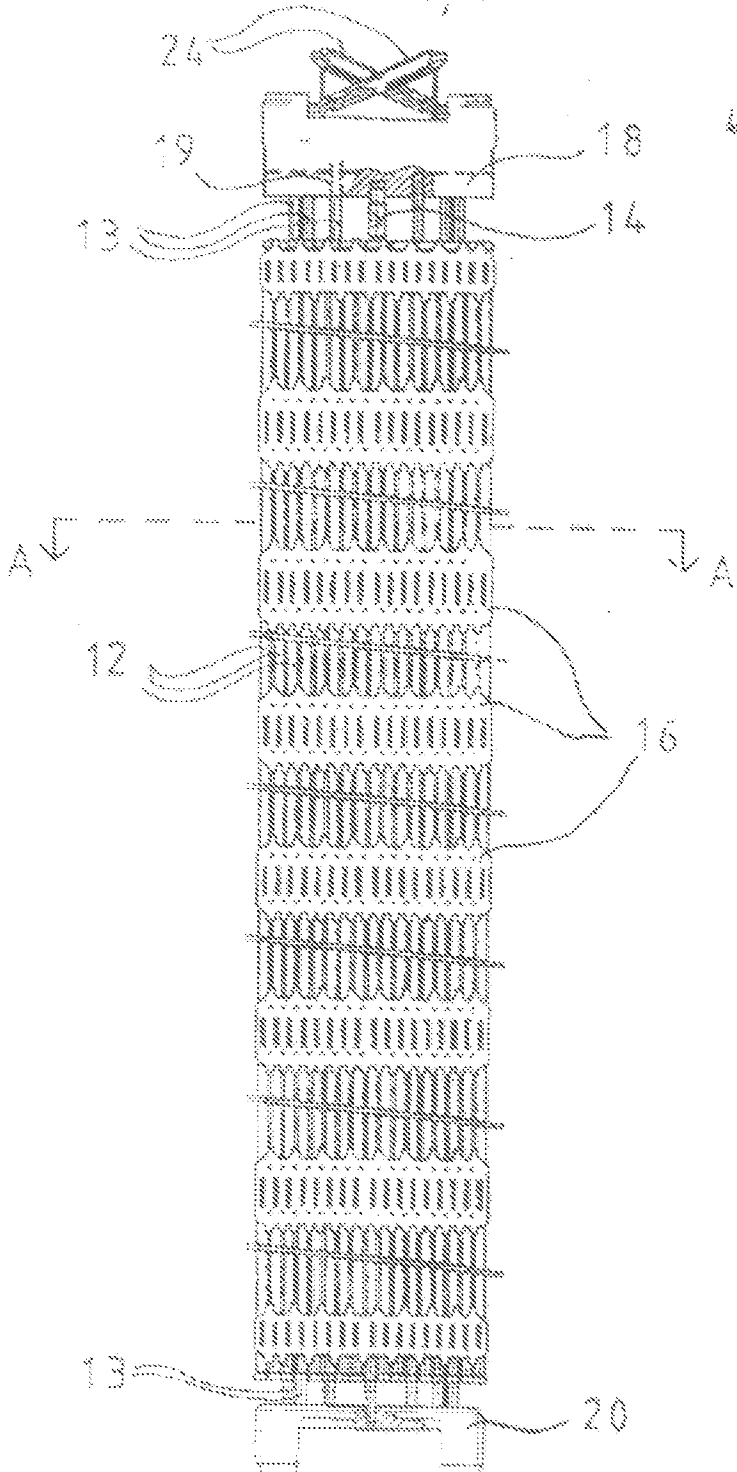

FIG 1

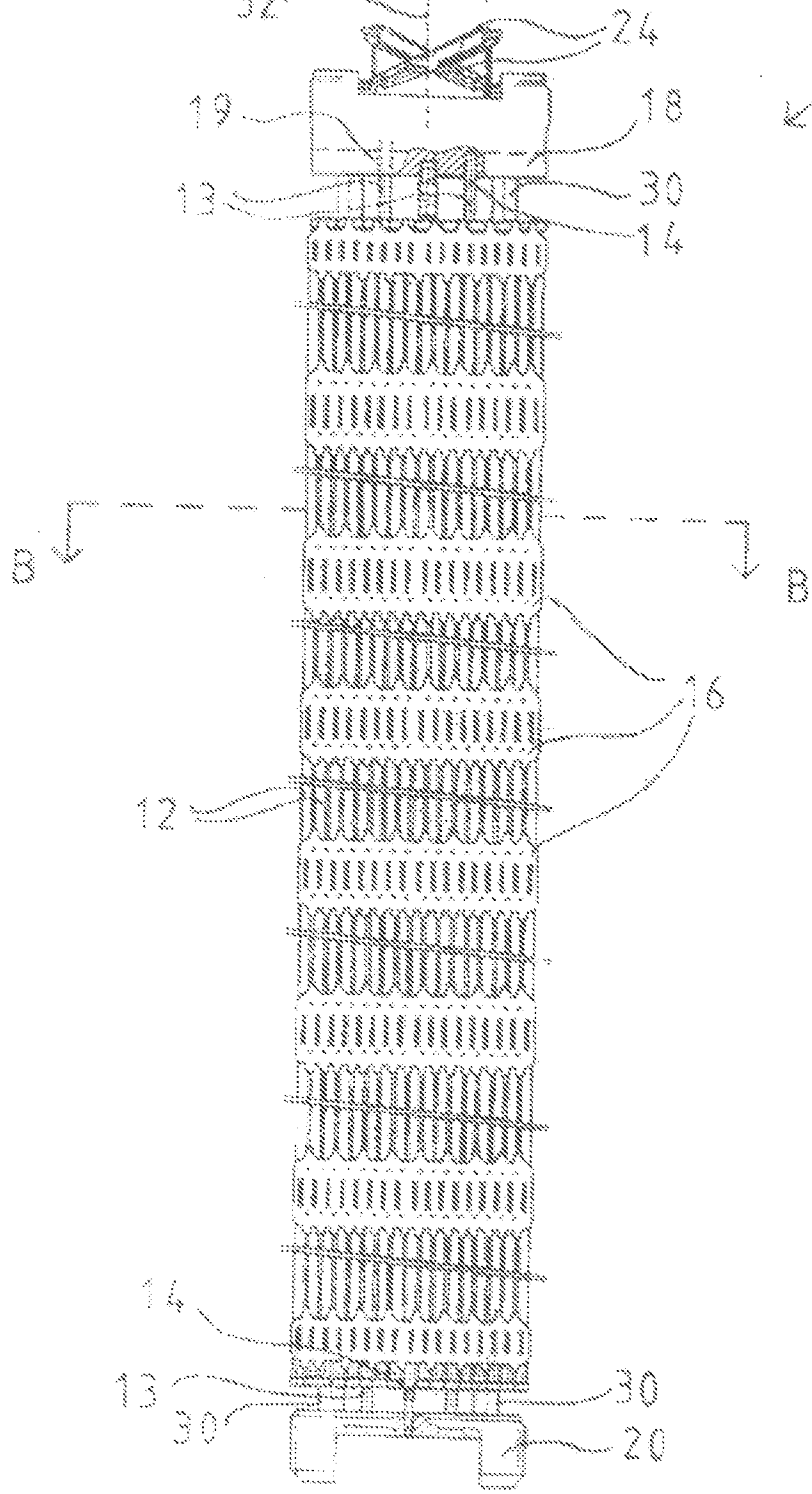

FIG 3

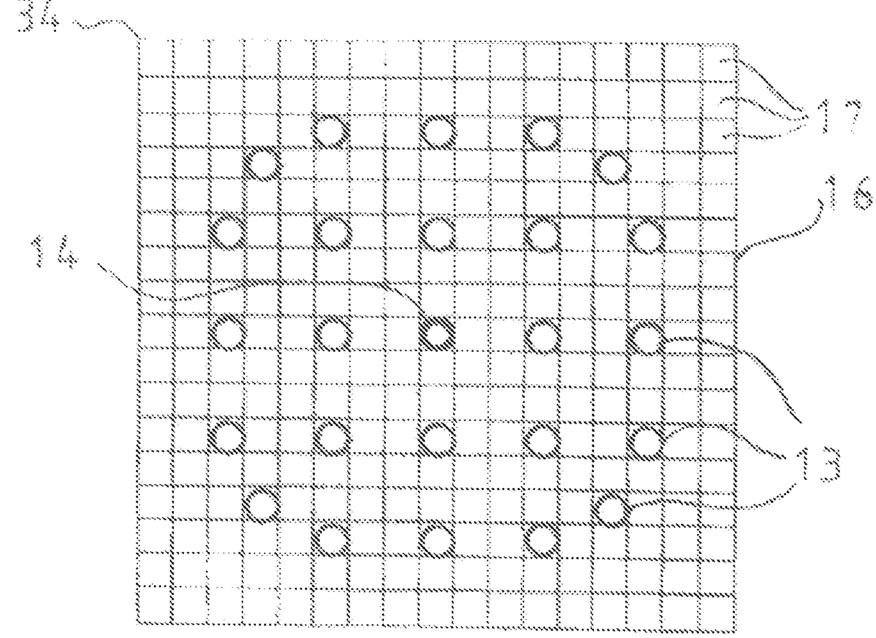

FIG 2

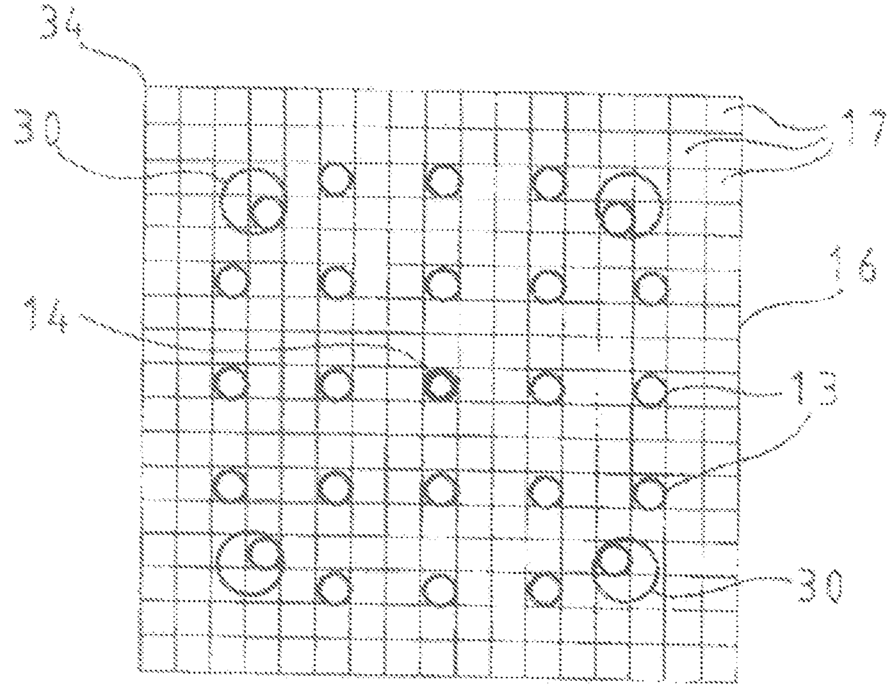

FIG 4

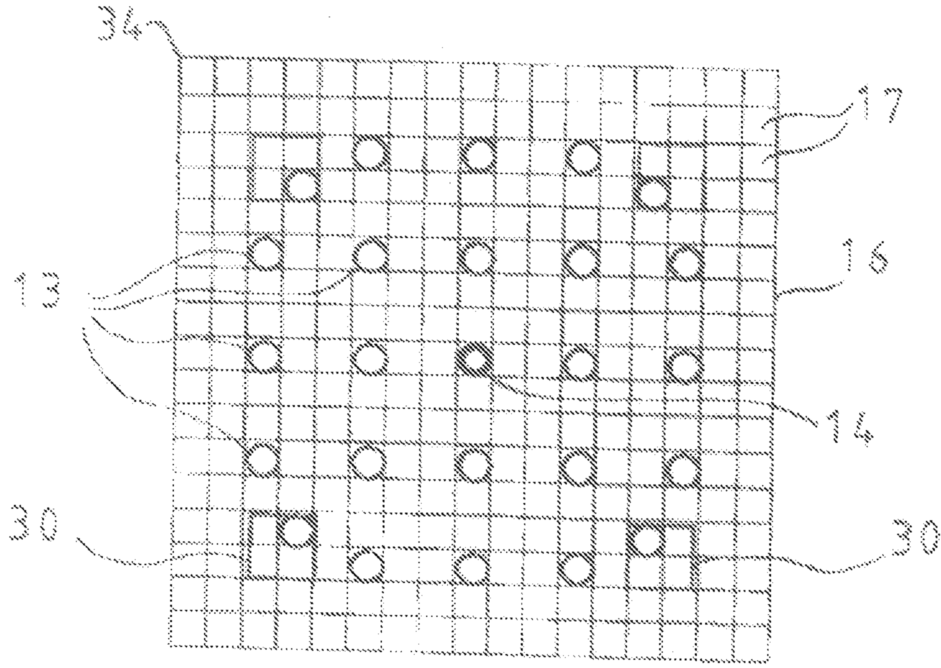

FIG 5

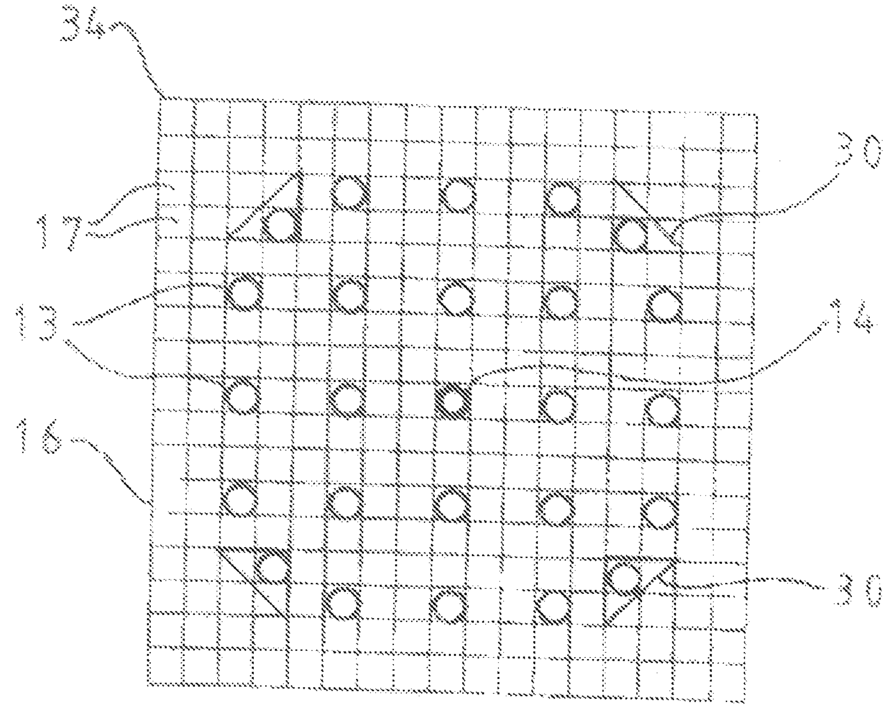

FIG 6

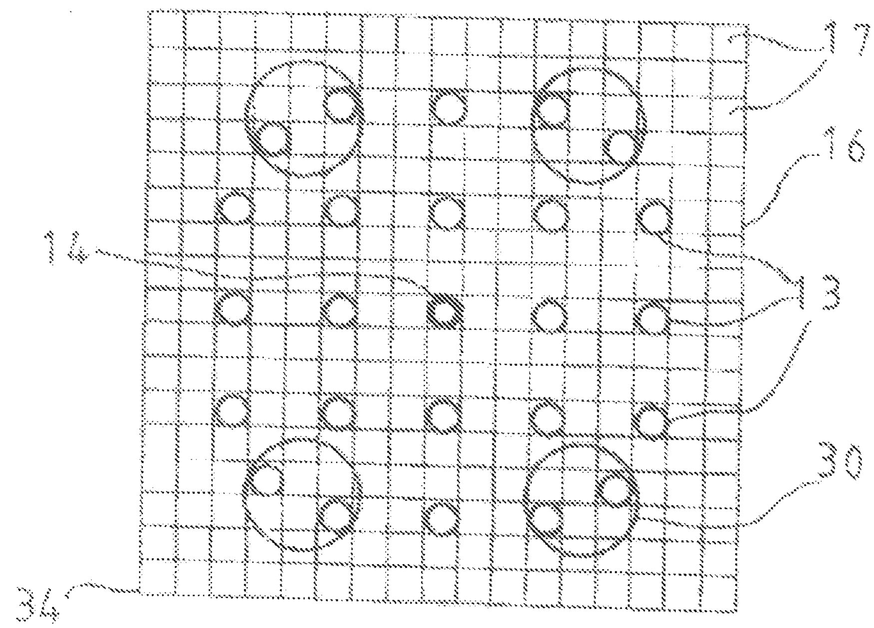

FIG 7

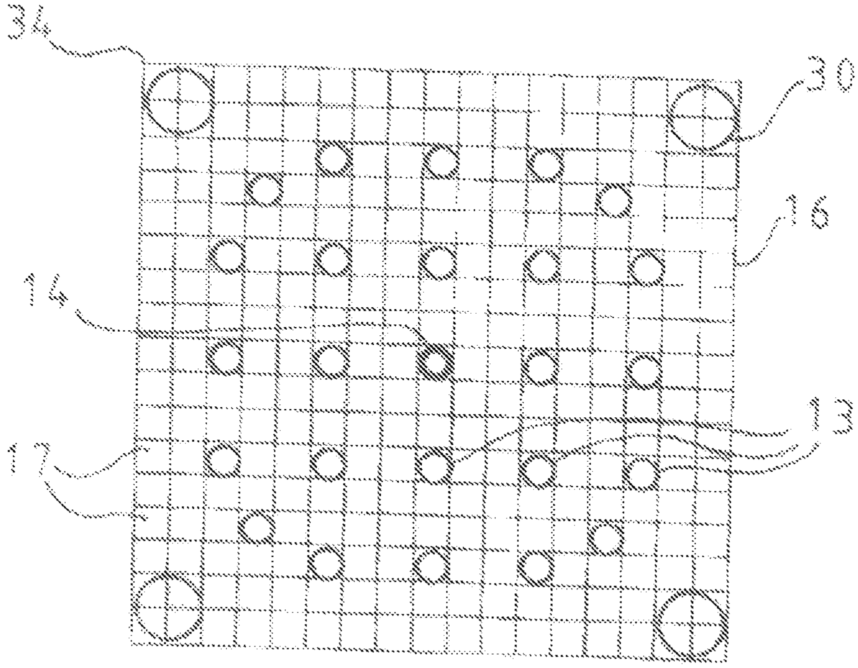

FIG 8